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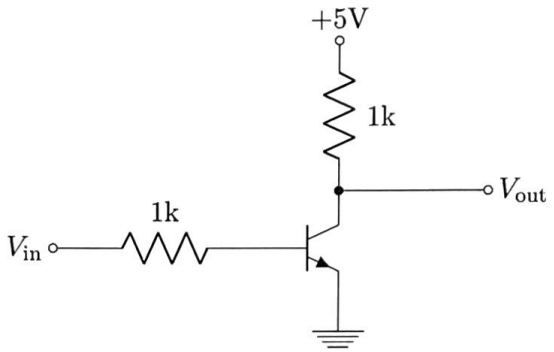
Electronics for Scientists

Exam 2: Transistors and Op-Amps

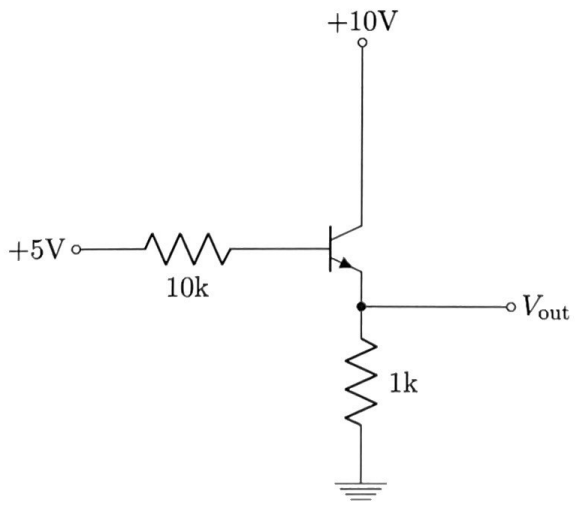
Instructions

Complete the following exercises to the best of your ability. Do not forget your units and show your work! Answers without units or supporting work will be graded incorrect.

1. A 10 V AC source is input into the following circuit. Sketch the input and output voltages as a function of time on the same graph. [20 points]

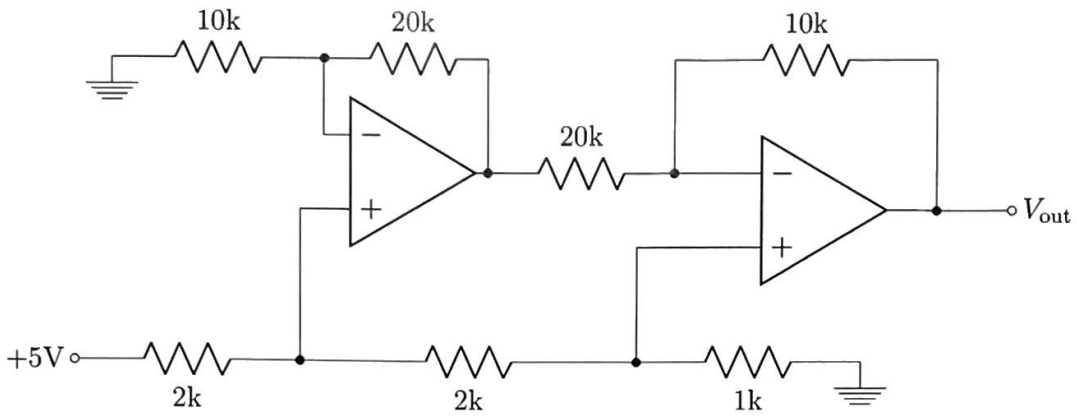


2. The following circuit contains a transistor where $\beta = 100$. A DC voltage of +5 V is applied to the input. What is V_{out} assuming an infinite load across V_{out}? What is V_{out} with a 100 Ω load across V_{out}? [20 points]

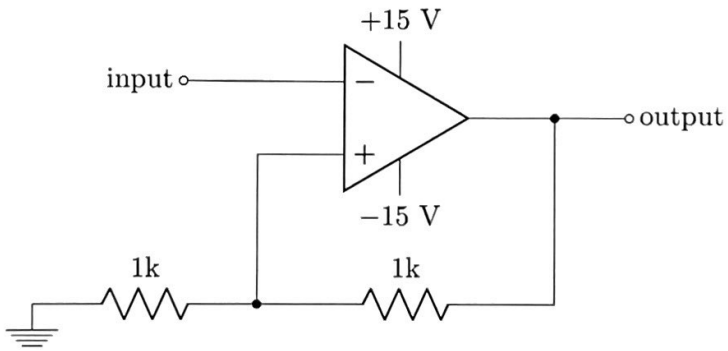


3. Design an op amp circuit that takes a 5 V AC signal and outputs an AC signal that swings from 0 to 15 V without clipping. You may assume an ideal op amp. You may also use any DC voltages as additional inputs into your circit. A circuit that inverts the signal is acceptable (and likely simpler). Make sure that you label the supply voltages for your op amp! [20 points]

4. Determine the output voltage of the below op amp circuit. [20 points]



5. A student constructs the following circuit in attempt to produce a clock output that flips between -15 V and $+15$ V from a 5 V AC input source. Why doesn't the circuit work as intended? There are many ways to fix the circuit. How could the input be changed such that the circuit works as intended? Alternatively, how could the resistors be changed such that the circuit works as inteded? Pick one of these two corrections and sketch the input and output as a function of time. [20 points]



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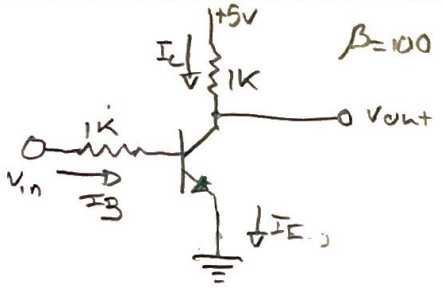
P1:



$\beta = 100$ $I_C = \beta I_B$ $I_C = 0.94\ A$

$V_{in} = 10V$

Transistors amplify current!

is transistor on when $V_{in} < 0$?

Current loops

$5v - I_C(1K) = V_{out}$ ✓

$V_{in} - I_B(1K) - 0.6V = 0$ ✓

$I_B(1K) = 9.4v$ learn in terms of V_{in}!

$I_B = 9.4\ ma$

$I_C = \beta I_B$

$= 100(9.4ma)$

$I_C = 0.94A$

$I_B = \frac{V_{in} - 0.6V}{1K}$

$5v - 100I_B(1K) = V_{out}$

$5v - I_C(1K) = V_{out}$

$5v - (0.94A)(1K) = V_{out}$

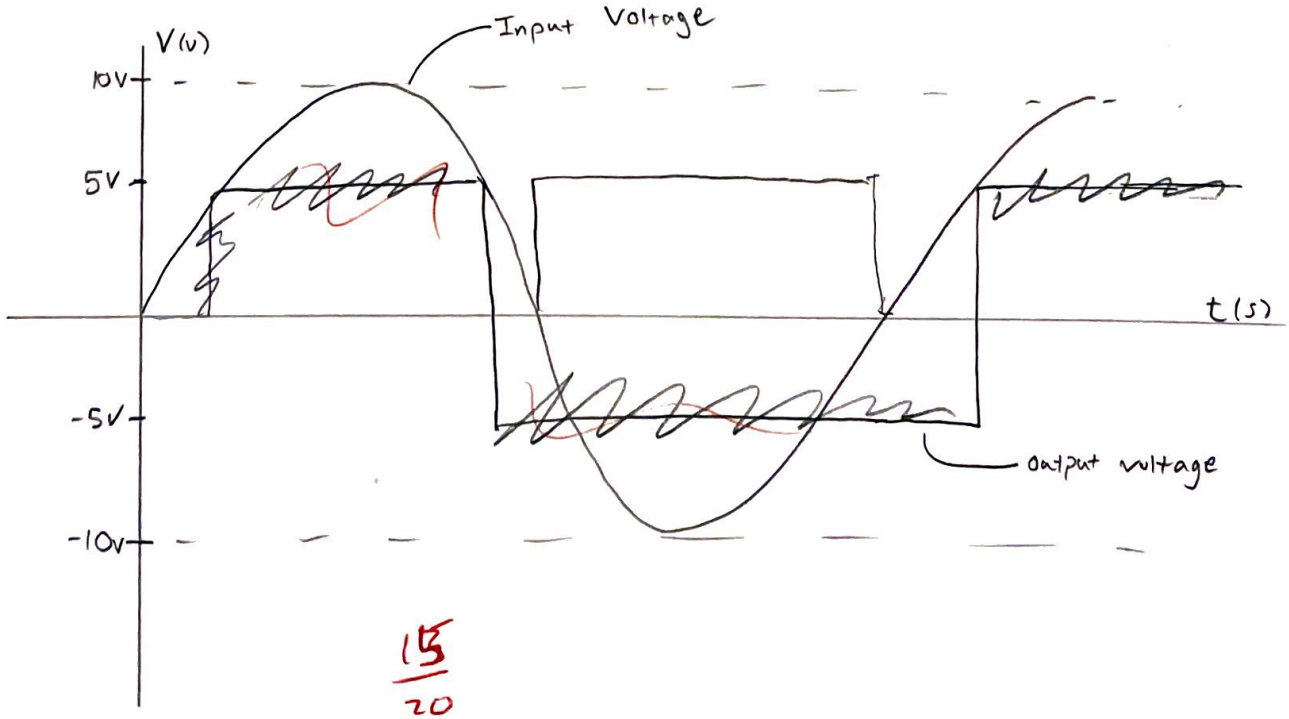
$V_{out} = -935v$

Vout technically isn't possible so it will oscillate between -5 and 5v

0

-5

Input and output



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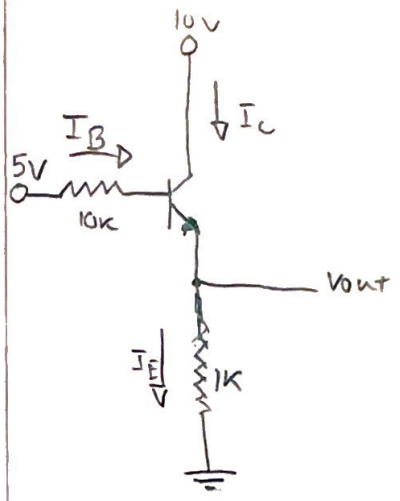
P2:



Current loops $I_E = \beta I_B$

$5V - I_B(10K) - 0.6V - I_E(1K) = 0$

$4.4V - I_B(10K) - 100I_B(11K) = 0$

$4.4V - I_B(110K) = 0$

$I_B(110K) = 4.4V$

$I_B = 4.0 \times 10^{-5} A$

$I_B = 40\,mA$

$I_C \approx I_E = 4mA$

$V_{out} - I_E(1K) = 0$

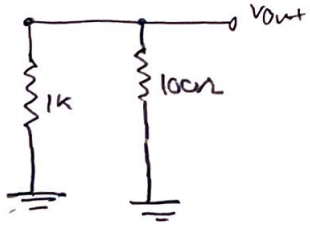
$V_{out} = I_E(1K)$

$V_{out} = 4mA(1k)$

$V_{out} = 4V$

$V_{out} = 4V$ ✓

With load



$5V - I_B(10K) - 100I_B(91\Omega) - 0.6V = 0$ ✓ (9100 I_B)

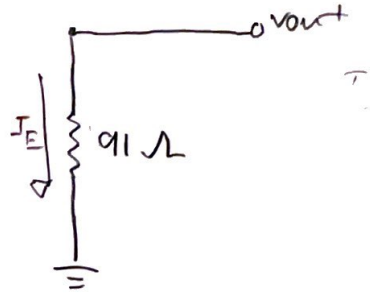
$I_B(19100\Omega) = 4.4V$ (~~10091~~)

$I_B = 4.3 \times 10^{-4} A$

$I_E = 4.3 \times 10^{-2} A$

-1

$R_{Eq} = \frac{100\Omega(1K)}{100\Omega + 1K} = 90.9\Omega = 91\Omega$ ✓



$V_{out} - I_E R = 0$ $\quad I_E = 4.3 \times 10^{-2} A$

$V_{out} = I_E R$

$V_{out} = 43\,mA(91\Omega) = 3.96V$

$V_{out} = 3.96V$

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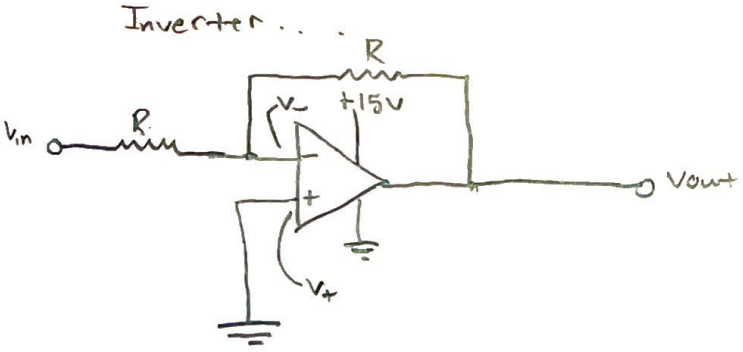
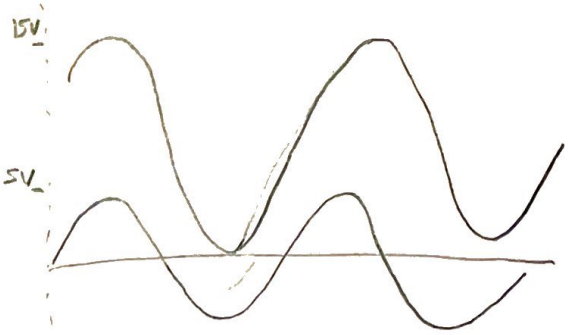
Inverter . . .



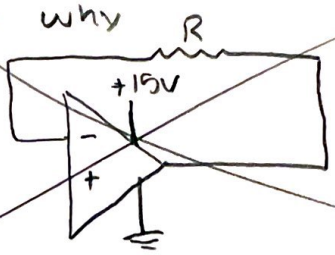


Golden rules say that in negative feedback,

- no current goes through the input
- V_+ & V_- are the same

∴ ~~The op amp has no choice but to oscillate between its power on it.~~ ?

~~Thus why~~

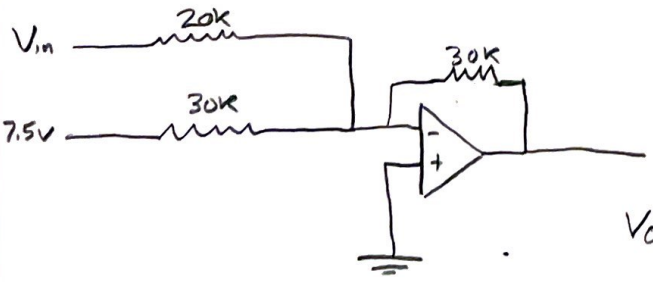


?

R = ? ? ?

~~This circuit will invert~~

-8



$$V_{out} = -30k\left(\frac{V_{in}}{20k} - \frac{7.5}{30k}\right)$$

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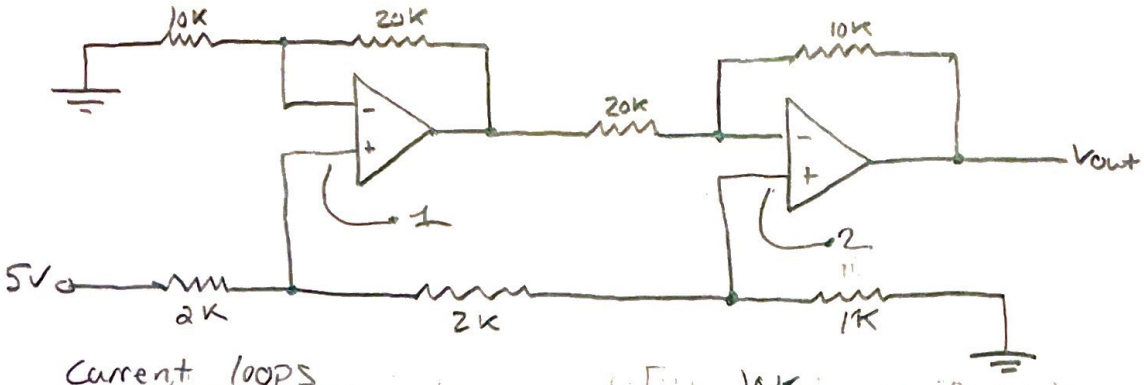
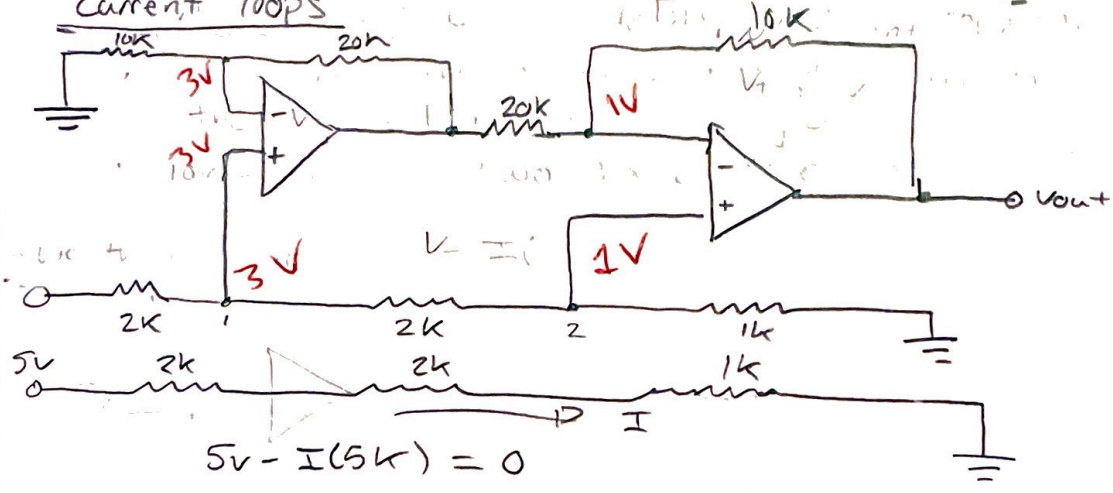
P4:



Current loops



$5v - I(5k) = 0$

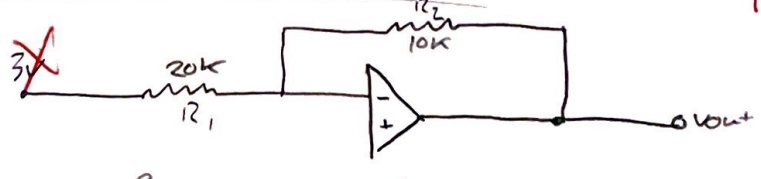
$I = \frac{5v}{5k} = 1mA$ ✓

Point 1

$5v - I(2k) = 5v - 1mA(2k) = 5v - 2v = 3v$ ✓

no current through inputs

point 2 ??



$v_{out} = \frac{R_2}{R_1+R_2} v_{in} = \frac{10k}{30k}(3v) = 1v$ -1

$V_{out} = 1V$

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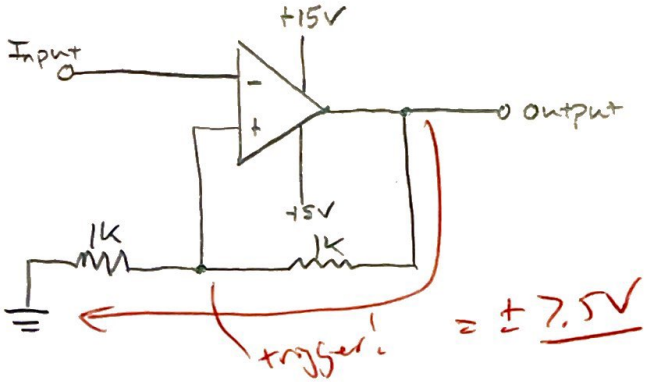
P5:



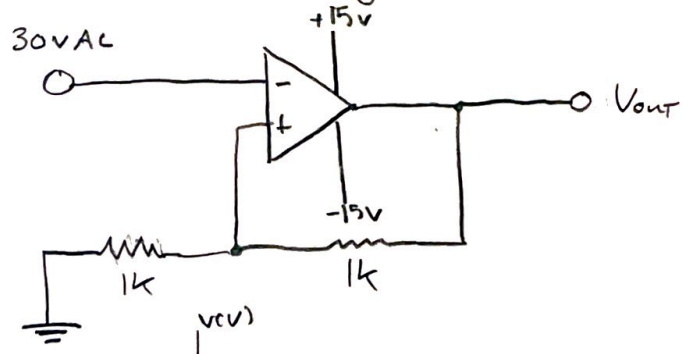
$= \pm 7.5V$

Want output between (-15V) and (15V)

$V_{in} = 5V$ $V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$ -3

$V_{out} = \frac{1K}{2K} V_{in} = \frac{1}{2} 5 = 2.5V$

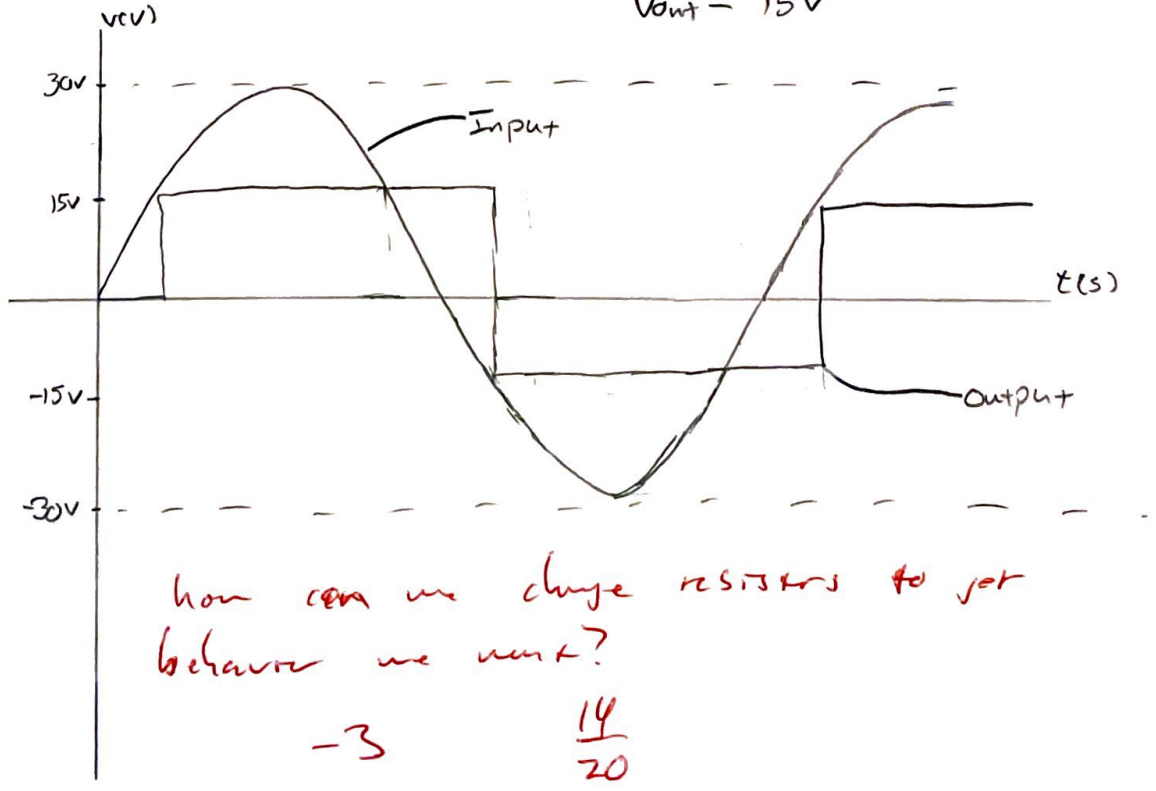
The input needs to be ~~8x~~ ? times higher for this circuit to go between (-15V) & (15V)



$V_{out} = \frac{1}{2} V_{in}$ $= \frac{1}{2} V_{in}$

$= \frac{1}{2}(30V)$ $= \frac{1}{2}(-30V)$

$V_{out} = 15V$ $V_{out} = -15V$



how can we change resistors to get behavior we want?

-3

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